

Landscape change on burned blanks in Daxing'an Mountains

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Abstract: Daxing'an Mountains was one of the most important forest areas in China, but it was also an area which was prone to suffering forest fire. The catastrophic forest fire that occurred in Daxing'an Mountains on May 6, 1987 devastated more than 1.33×10^6 hm² of natural forests, which led to the formation of some mosaic areas with different burn intensities. Two forest farms of Tuqiang Forest Bureau (124°05'-122°18'E, 53°34'-52°15'N) were chosen as a typical area to analyze the post-fire landscape change by drawing and comparing the two digital forest stand maps of 1987 and 2000. The landscape lands of forest were classified into 12 types: coniferous forest, broadleaf forest, needle-broadleaf mixed forest, shrub, nursery, harvested area, burned blanks, agricultural land, swamp, water, built-up, grass. The results showed that: 1) The burned blanks was almost restored, some of them mainly converted into broadleaf forest land during the process of natural restoration, and coniferous forest land by the artificial reforestation, and the others almost changed into swamp or grass land; 2) The proportion of forest area increased from 47.6% in 1987 to 81.3% in 2002. Therefore, a few management countermeasures, such as the enhancing people's consciousness of fire-proofing and constructing species diversity, were put forward for forest sustainable development.

Keywords: Landscape change; Burned blanks; Daxing'an Mountains

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Introduction

The forest in Daxing'an Mountains is the largest forest resource in China, and is indispensable as sources of harvested products. Unfortunately it was often threatened by natural and human-induced disturbances. It is widely known that fire poses the greatest threat and plays an important role in shaping the landscapes under natural conditions (Boyчук *et al.* 1997; Hanes 1971). On May 6, 1987, a catastrophic forest fire occurred in Daxing'an Mountains and devastated more than 1.33×10^6 hm² of natural forest, which led to the formation of some mosaic areas by different burn intensities. The spatial extent and heterogeneity of the fire provided an ideal opportunity to study the post-fire landscape change.

Although an ideal state of forest landscape management is to resume forest's natural state, it is difficult to reconstruct the natural state of the boreal forest. The site conditions sometimes do not fit the vegetation to restore, because boreal forests are usually species-poor with only a small number of woody species (Wright *et al.* 1982). However, a good post-disturbance revegetation pattern is important, for it has a direct influence on many ecological processes (Cormack *et al.* 2001; Edward 1992).

This study made a comparative analysis on the post-fire landscape change in Daxing'an Mountains, with a purpose to provide the basis for future forest resource management.

Study area

The study was carried out at Yuying Forest Farm and Fendou Forest Farm of Tuqiang Forest Bureau in Daxing'an Mountains (124°05'-122°18'E, 53°34'-52°15'N), in Heilongjiang Province (Fig. 1), and the total study area was about 1.2×10^5 hm². The climate of this area is cool and dry. A annual mean temperature is -4.94 °C, and the extreme lowest temperature is -53 °C. The average annual precipitation is 43.2 cm, over 75% of which falls in July and August.

The forest belongs to the most northern part of the global boreal forest biome. The local species composition is very poor, dominated by larch (*Larix gemelini*), *Pinus sylvestris* var. *mongolica* or birch (*Betula platyphylla*), and ground layer is dominated by some shrubs such as *Ledum palustre*, *Vaccinium vitis-idaea* or some other lichens.

The topography of the study area consists of rolling hill, with gradients ranging from 3% to 10% and elevations ranging from 380 m to 890 m above sea level. Most of the hills are facing to north-south. The main geologic formation in the study area is granite, in combination with a little limestone or others. Because of the long cold winter, permafrost is often distributed at the depth about 3 m. With geological and topographical factors, podzolic soil is the dominant type upper the hill, while Stagni-Perudic Cambosols and Spodic Bori-Perudic Cambosols are dominant in the middle, and Hemi-Orthic Histosols domains the down hill.

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The fire in 1987 in two forest farms of Tuqiang Forest Bureau burned out more than 5.0×10^4 hm² of natural forest, about 60% of the study area. And the forest coverage rate

decreased from 90.21% in 1986 to 58.42% in 1987. Tuqiang was one of the most severely burned bureaus during this fire catastrophe.

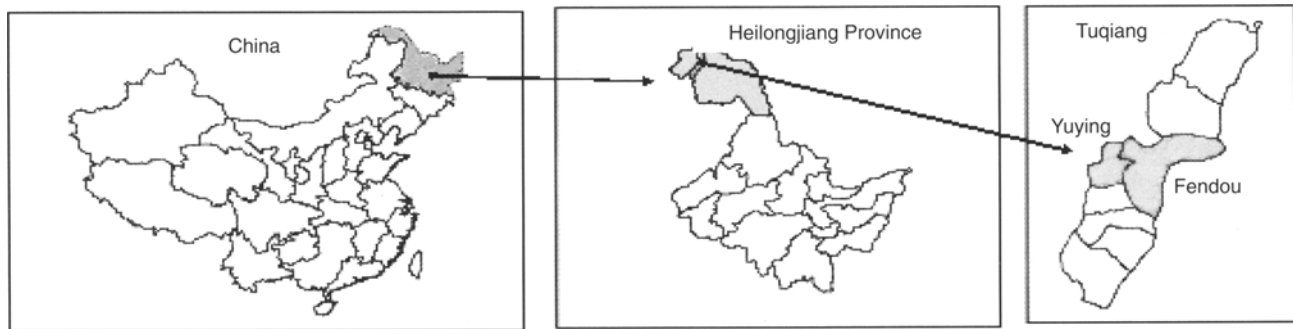


Fig. 1 Location of the study area

Methods

According to the data in two maps of forest stand (1987 and 2000), landscape maps were digitized to generate their related data, which were also used to get the attributes of each forest patch, including the forest site type, dominant forest species, fire burn intensities, *etc.* Landsat Thematic Map (TM) images (on December 7, 1987 and September 14, 2000) and the field data collected in the summer of 2002 and 2003 were used as reference data. The map of fire burn intensities derived from 1987 TM images.

Four classes of fire burned areas were used to characterize the heterogeneity of the fire in severity: unburned (no sign of fire effects), lightly burned (older trees or even the most fire-susceptible species survived, with only stems scorched, and soil organic layer remained), moderately burned (all trees of fire-susceptible species killed, but older trees of fire-tolerant species leaved), severely burned (all trees killed), (Turner *et al.* 1997; Susan *et al.* 1993).

In this paper the landscape lands of forest covered were classified into 12 types: coniferous forest, broadleaf forest, needle-broadleaf mixed forest, shrub, nursery, harvested area, burned blanks, agricultural land, swamp, water, built-up, grass. The two digital forest stand maps were managed and analyzed by using Arcview and Arc/info GIS tools (Fig. 2, 3).

Results

Landscape structure

The patch number, area, and percentage of each landscape type area for the year of 1987 and 2000 were shown in Table 1. In 1987, the severely burned area occupied more than 44% of the total study area, constituting a continuous matrix. The coniferous forest was the second largest landscape type, which was mainly distributed in the unburned

area. Needle-broadleaf mixed forest was the third largest landscape type, which was the prophase of climax community in this area after natural or anthropogenic disturbance. The harvested area ranked the fourth; the main reason was the strategy of clear cutting after the forest fire in moderately and severely burned area or even in lightly burned area, as a result, some remained fire-tolerance trees were also cut down after the fire.

There were almost no nursery area and agricultural land, since the local people made living by logging, and the forest regeneration was also under natural state before 1987. The built-up area was almost zero, because nearly all the residential areas were burned out by the fire, and most of the people had to abandon their home.

The landscape in 2000 was more heterogeneous compared to that in 1987. The proportion of forest area increased from 47.6% in 1987 to 81.3% (Table 1, sum of the first 3 types). All the forest landscape types increased stably. Among the forest landscape types, coniferous forestry was the dominant, about 47.6%, for the intensive planting after fire. The broadleaf forest was the second, which was the subclimax forest after fire disturbance, sprouting of birch (*Betula platyphylla*) from burned site was the main form for restoration. The needle-broadleaf mixed forest was the third, which partly formed by human interfered regeneration in moderately burned area. The area of burned bland became zero. Nursery area expanded to produce young seedlings for artificial reforestation.

Change of the landscape

The number of landscape component types in 2000 was relatively more than that in 1987, and the distribution was also slightly more homogeneous than that in 1987 (Fig 2). The area of broadleaf forest increased more than 3 times (Table 1). Fire promoted the establishment or regeneration of these broadleaf trees. The conversion table (Table 2) showed that 37.4% of this type did not change, and about

37.1% changed into coniferous forest, 21.9% converted to needle-broadleaf mixed forest. The results really indicated the successional trends. Table 3 indicated that, about 35.5% of all the broadleaf area was converted from coniferous, 36.3% converted from burned blanks and only 7.9% was left after 1987. Comparing with the two distribution maps of the vegetation, most of the broadleaf forest in 2000, which was coniferous forest in 1987, was located in the light and moderately burned area. The main reason was the wrong policy of clear cutting. In fact, after the deforestation, the deciduous trees often had a strong ability of germination to form broadleaf forest.

The number of burned blank patches had also obviously changed (Fig. 2), which decreased from 103 to zero (Table 1), and almost no fires were recorded. On the burned blanks, 49.4% of the area was converted to coniferous forest, resulted from intensive human reforestation. After the fire, with the help of local government, people created the terrace and

planted the coniferous seedlings for revegetation. The conversion rate between the burned blanks and broadleaf forest was 18% (Table 2), and most of which were birch (*Betula platyphylla*) and *Populus davidian*. Generally the succession time from burned blanks turning into broadleaf forest was about 35-40 years. If the site condition is well enough, it will take 10 year to establish a closed canopy. The conversion rates between burned blanks to swamp or grass were both inferior to the rate between burned blanks to broadleaf forest (Table 2). From Table 3, 70.8% of the swamp area and 61.9% of the grass area were converted from burned blanks in 1987. The swamp was always coincided with the fluvial terrace or valley bottom, with frozen earth under ground. The dominant species were usually *Carex schmidtii*, *Carex meyeriana*, accompanied by some shrubs such as *Betula ovalifolia*, *fruticosa*. The grassland was common with poor site conditions for infertile soil and lack of water.

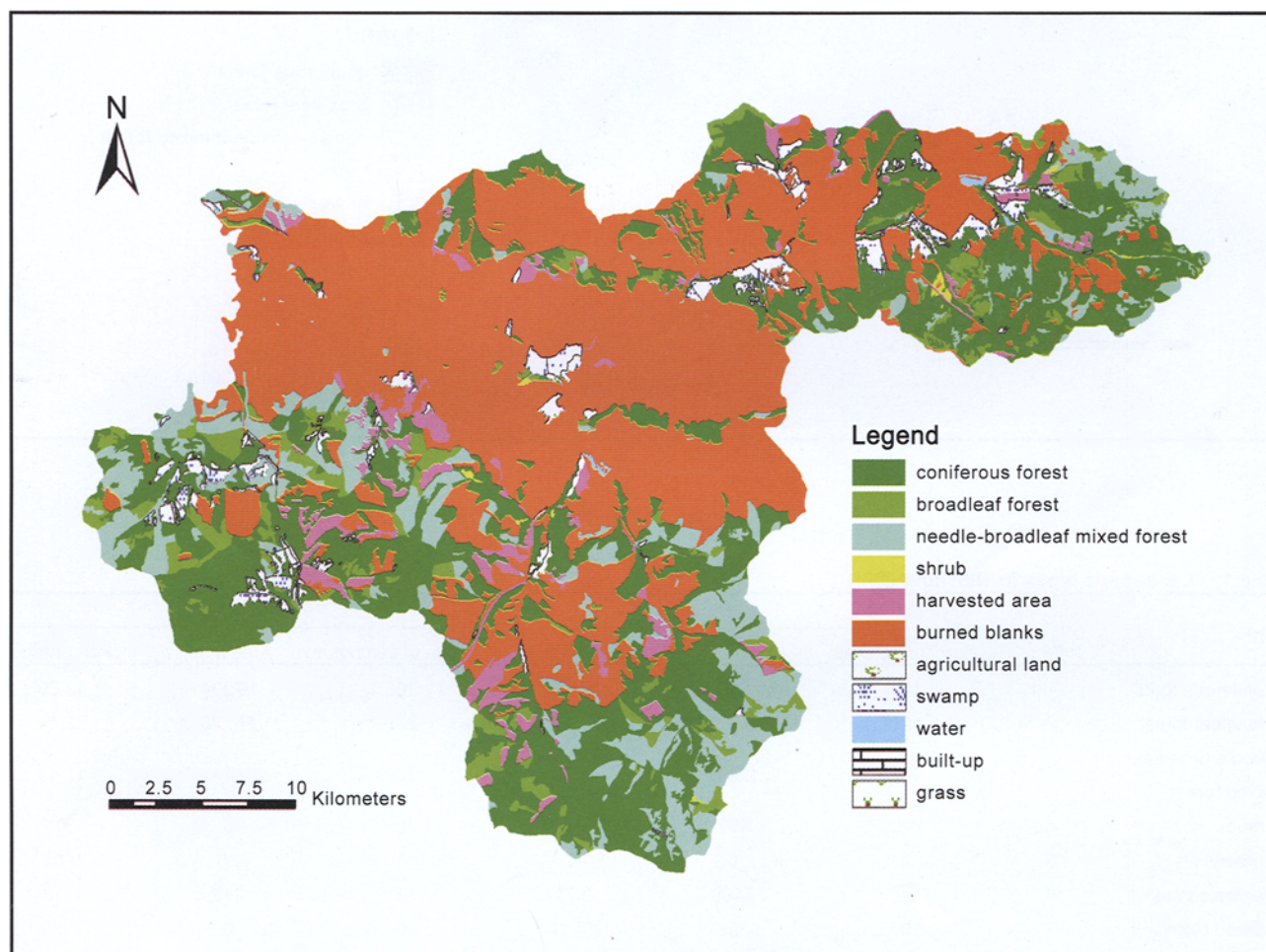


Fig. 2 Forest stand map in 1987

Harvested area was the second largely decreased type (Fig 2). Its area dropped from 4 466 hm² to 212 hm² (Table 1). Two factors caused this change: Firstly, the initial harvested area changed into other landscape types. Of the harvested area in 1987, about 55.5% was converted to

coniferous forest on count of the human planting, and partly it was also the result of natural succession, because most of areas were distributed on the lightly or moderately burned area. Under the wrong policy of clear cutting, all the survivors were cut down. But the seeds under ground be-

fore fire and those dispersed into the area from surrounding unburned forest germinated and became the pioneer. Secondly, the new harvested area cannot generate now. It

is illegal to cut any natural forest, under the new policy of "natural forest protection".

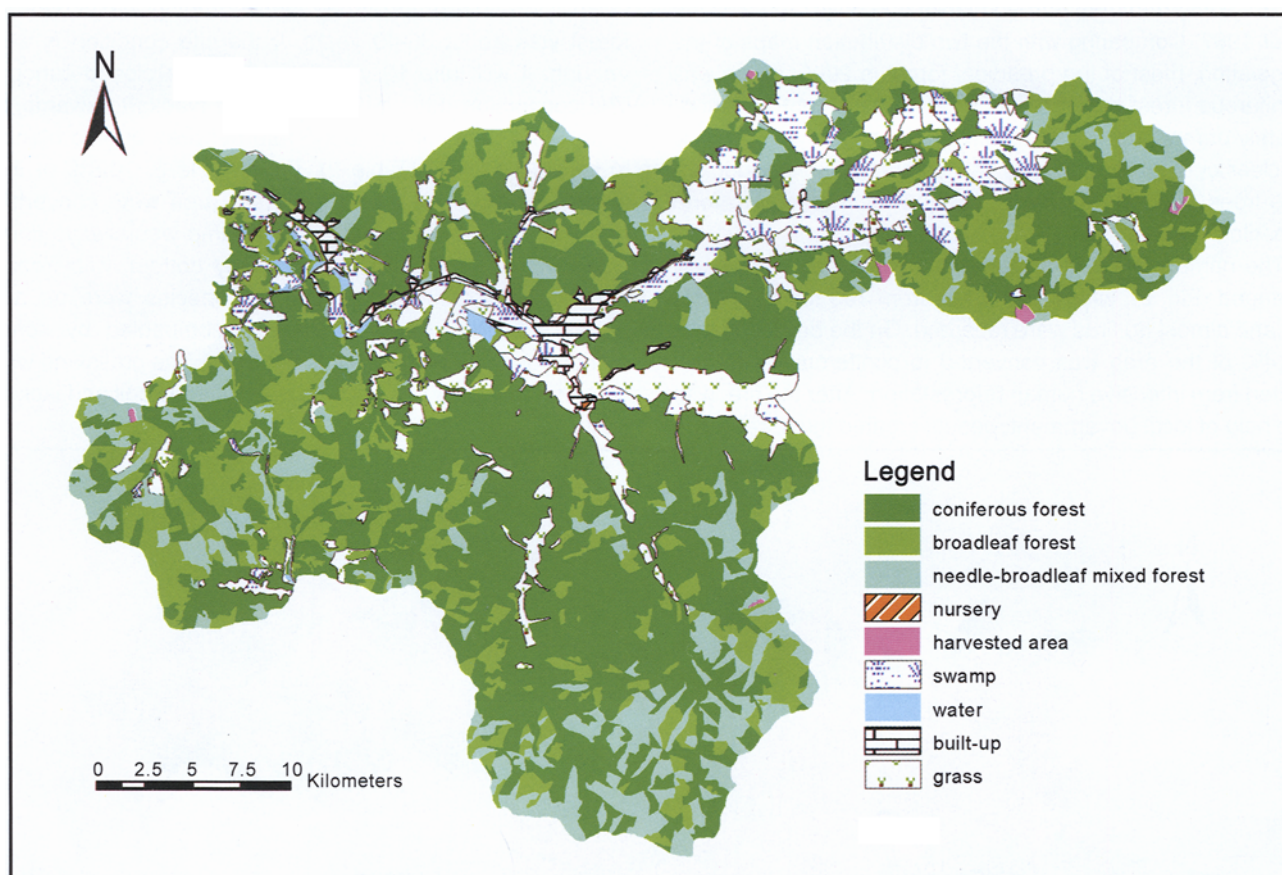


Fig. 3 Forest stand map in 2000

Table 1. Landscape types in 1987 and 2000

Type	Type code	1987			2000		
		Num. of patches	Area /hm ²	Percentage	Num. of patches	Area /hm ²	Percentage
Coniferous forest	1	154	38498	31.95	165	57204	47.59
Broadleaf forest	2	123	5809	4.82	239	26726	22.24
Needle-broadleaf mixed forest	3	142	12997	10.79	159	13746	11.44
Shrub	4	13	177	0.15	0	0	0
Nursery	5	0	0	0	1	25	0.02
Harvested area	6	88	4466	3.71	6	212	0.18
Burned blanks	7	103	53587	44.47	0	0	0
Agricultural land	8	1	27	0.02	0	0	0
Swamp	9	77	4132	3.43	54	9409	7.83
Water	10	21	188	0.16	16	446	0.37
Built-up	11	1	1	0.01	20	1655	1.38
Grass	12	34	614	0.51	97	10772	8.96

Notes: In the landscape type, the burned blanks only include the severely burned areas.

The conversion rate of shrub was the highest from 1987 to 2000. More than 59.5% of the shrub area was trans-

formed into that of the coniferous. The site with shrub was mainly lightly or severely burned area. The shrub at the lightly burned area was always distributed by the river sides with *Betula albo-sinensis* Burk, *Vaccinium vitis-idaea*, *Ledum palustre* as the dominant species, after the fire some of the

coniferous trees remained. They can easily restore through seed dispersal.

In order to remove burned remnants, people built a lot of skidding trails. This caused the increase of number of built-up patches.

Table 2. Transfer matrix of each type from 1987 to 2000

(%)

In 1987	In 2000											
	1	2	3	4	5	6	7	8	9	10	11	12
1	49.794	24.697	16.482	0	0	0.403	0	0	2.387	0.092	0.037	6.107
2	37.446	37.091	21.867	0	0	0.165	0	0	0.258	0.180	0.114	2.879
3	44.279	26.411	26.972	0	0	0.014	0	0	0.288	0	0.169	1.867
4	59.469	8.706	0.812	0	0	0	0	0	17.152	0	0	13.862
5	0	0	0	0	0	0	0	0	0	0	0	0
6	55.454	27.664	3.429	0	0	0.324	0	0	4.614	0	0.347	8.168
7	49.385	18.092	4.419	0	0.047	0.053	0	0	12.471	0.723	2.353	12.456
8	0.169	0	0	0	0	0	0	0	0	0	0	99.831
9	23.301	15.248	2.003	0	0	0	0	0	35.193	0.237	7.713	16.304
10	23.124	15.362	2.028	0	0	0	0	0	42.180	1.042	0.119	16.145
11	41.101	0	58.899	0	0	0	0	0	0	0	0	0
12	33.148	15.778	4.254	0	0	0	0	0	2.787	0.268	3.687	40.078

Notes: Rank 1-12 is identical to the type code in Table 1

Table 3. Area contribution of each type in 2000

(%)

In 2000	In 1987											
	1	2	3	4	5	6	7	8	9	10	11	12
1	33.420	3.754	9.994	0.183	0	4.304	46.231	0.001	1.680	0.077	0.001	0.356
2	35.505	7.964	12.769	0.057	0	4.600	36.278	0	2.355	0.109	0	0.363
3	46.197	9.154	25.423	0.010	0	1.111	17.277	0	0.603	0.028	0.004	0.191
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0.079	0	0	0	99.921	0	0	0	0	0
6	74.230	4.534	0.842	0	0	6.907	13.487	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0
9	9.719	0.157	0.394	0.320	0	2.172	70.815	0	15.393	0.846	0	0.182
10	7.934	2.315	0	0	0	0	86.748	0	2.192	0.441	0	0.369
11	0.845	0.393	1.318	0	0	0.929	75.957	0	19.178	0.014	0	1.367
12	21.740	1.531	2.235	0.226	0	3.363	61.853	0.246	6.236	0.283	0	2.285

Notes: Rank 1-12 is identical to the type code in Table 1.

Conclusions and suggestion

According to the comparison of forest areas between 1987 and 2000, the major patterns of landscape change were gained in the study region after the fire disturbances. The change of the landscape mainly depended upon the disturbance pattern, and the site conditions and intensity of the anthropogenic disturbance. According to the above analysis, the conclusions were as follows:

The change is evident with its stable trend. Large blocks of the mature forest are broken into pieces with burned blanks and unburned area. After 15 years, the burned blanks underwent two stages: firstly, from burned blanks to early successional stage of shrub and broadleaf forest; secondly, from broadleaf and needle-broadleaf forest to

conifer-dominated types. Today, even though the change of landscape has not yet reached a stable equilibrium, the climax community has already established largely, and the landscape change trend is stable.

The change of landscape is controlled by both natural succession and human activities. Succession of fire-disturbed forests is often very slow and unpredictable, because of complex interactions factors among fire intensity as well as topographic attributes (slope, aspect and elevation), initial landscape patterns, post-fire soil and climatic conditions. While an abundant and viable seed supply is the same important (Kozłowski 2000). At the same time, and anthropogenic disturbance also has a strong effect on the variability in post fire landscape. In order to shorten the time of restoration, management techniques are being developed to regenerate the coniferous forest

(*Larix gemelini*, *Pinus sylvestris* var. *mongolica*). Of the whole Tuqiang Bureau, the area of the artificial regeneration was $4.13 \times 10^4 \text{ hm}^2$, i.e., about 22.3% of the total area, and accounted for 46.1% of the severe burned area.

In order to prevent the forest fire like the 1987' fire, the following measures should be taken:

(1) Development of the coniferous forest should not be as the sole aim, even though coniferous forest has a higher economic value than the broadleaf trees (Naveh *et al.* 1994). Any plan for managing forest landscape structure needs to identify the opportunities and constraints of existing patterns (Spies *et al.* 1994; Nakagoshi 2000).

(2) The management agencies should strengthen the consciousness of fireproofing. It is believed that forest fire management agencies have lot of success in reducing the amount of fire disturbance. However, fire disturbance can never be controlled to nearly the desired degree due to the difficulty or impossibility of suppressing sufficiently large fires. People should have a strong wariness of fireproofing in their daily life.

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